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Characterizing performance degradation through the analysis of V-I measurements in Nb3Sn accelerator magnets

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In the framework of the High-Luminosity Large Hadron Collider (HL-LHC) project, 11 T dipole and MQXF quadrupole magnets employing Nb₃Sn technology have been tested in short and long test configurations. Nb₃Sn magnets are more sensitive than NbTi magnets to a potential degradation of their conductors during production, testing and cycling operation. In the SM18 magnet test facility at CERN, new diagnostics tools and measurement procedures have been developed to investigate in detail performance limitations of Nb₃Sn accelerator type magnets, most importantly through advanced V-I measurements extracted from voltage taps on conductor sections as well as entire coils. For the analysis of performance limitations, a combination of data is studied, including temperature and ramp rate dependency of quench currents, and V-I measurements. A leading hypothesis for the cause of erratic quench behaviour and decaying voltages on current plateaus is the presence of an inhomogeneous defect in the Rutherford cable. Current redistribution for bypassing the defect takes place through a diffusion process, which leads to a decaying voltage over the affected cable sections. Using the simulation software THEA, the general behaviour of this phenomenon has been studied. Good qualitative agreement is found between model and magnet test results. The research is essential for better understanding performance degradation and for achieving a more robust magnet production considered essential for large-scale application of high field Nb₃Sn accelerator magnets.

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